RADIANT LIGHT AND HEAT[1]

IV.

Radiation and Absorption—Celestial Applications.

THE continuous emission of light and heat from the sun and stars through long periods, consisting of millions of years, cannot fail to strike us with amazement, more especially if we regard the great intensity of this radiation. It has been conjectured that the amount of solar heat received by the earth in one year would liquefy a layer of ice 100 feet thick, covering the whole surface of the earth. Now if we bear in mind that the solar heat reaching the earth at any time is only $\frac{1}{2300000000}$ of that which leaves the sun, we may obtain some conception of the enormous radiation from our luminary. It has been calculated by Sir William Thomson that if the sun were a hot solid body, such as carbon, its surface would cool in a few minutes of time. It therefore becomes an object of great scientific interest and importance to discover what is the nature of the peculiar machinery which enables the sun to continue, without interruption, discharging, as it does, into space such enormous quantities of radiant energy. The reply to this question can best be given by a detailed study of the surface of the sun. Whether viewed telescopically or spectroscopically, this surface is by no means that of a globe of uniformly luminous heated matter. Let us begin by examining this surface telescopically.

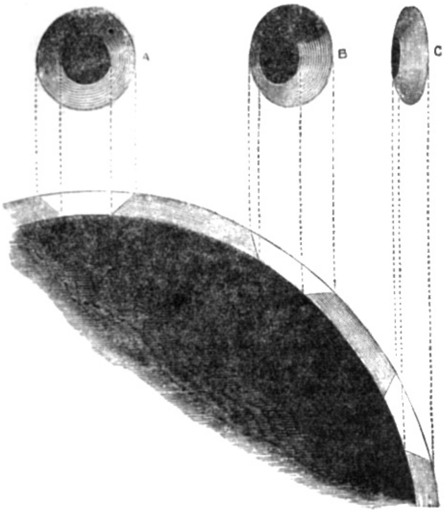

FIG. 11.

Shortly after the invention of the telescope Galileo and Scheiner showed that the disc of the sun is far from being uniformly luminous, since it frequently presents the appearance of having large *spots* on its surface. This is a fact which had been previously known to the Chinese. Further research showed that these black spots exhibit at least two degrees of darkness, consisting of a central intensely dark *umbra*, surrounded by a *penumbra*, or semi-dark border. We know now that even the umbra is not absolutely black, but consists of matter at a temperature comparatively low as regards the sun, but comparatively high as regards the earth. It was likewise found in the course of telescopic research that there are patches which are brighter, not darker than the average solar surface or *photosphere*, and these bright patches have been termed *faculæ*.

Thus we have on the solar surface things with three degrees of brightness, consisting of the normal solar surface or photosphere, of the spots which are darker than it, and of the faculæ, which are the brightest of all. The faculæ are more especially to be found in the neighbourhood of spots.

These are the phenomena which may generally be viewed on the sun's surface on any occasion by means of an ordinary telescope. Nevertheless, there are occasions on which we shall find no spots. Schwabe, a German observer, after forty years' patient study of the sun's surface, was successful in detecting a periodicity of these phenomena. There are certain years of maximum and other years of minimum sun-spot frequency, and the average distance from one maximum to the next, or from one minimum to the next, is about eleven years.

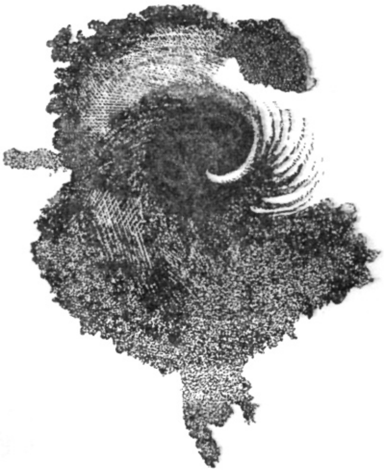

FIG. 12.

I have said nothing hitherto about the rotation of the sun, which was discovered by means of the apparent motion of the sun spots over the solar disc. This rotation takes place in about twenty-six days, and its plane is not far removed from the ecliptic, or that in which the earth moves around the sun, the two motions being likewise in the same direction. It has been discovered by Carrington that, as a rule, spots are confined to the regions around the solar equator, never by any chance appearing at the poles.

The nature of these spots has been a subject of much discussion. Professor Wilson, of Glasgow, was the first to bring forward evidence indicating that they are below the general level of the solar surface—pits, in fact, the bottoms of which are intensely black, while the sloping sides are less so. This evidence consisted in the fact that when near the sun's border that portion of the penumbra of a spot which is next the visual centre is hidden from our view, a behaviour which is illustrated in Fig. 11. Again, it has been pointed out by the Kew observers that the bottom of a spot is blacker because it is colder than the general surface, and they have likewise brought forward evidence to show that this diminution of temperature has

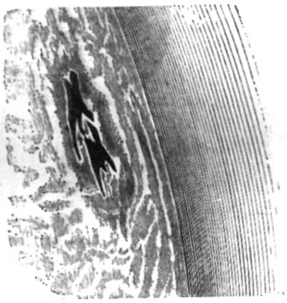

FIG. 13.

---

[1] Continued from vol. xxxii. p. 551.

probably been produced by the downrush of comparatively cold matter from above, a conclusion which has since been abundantly verified by spectroscopic observations.

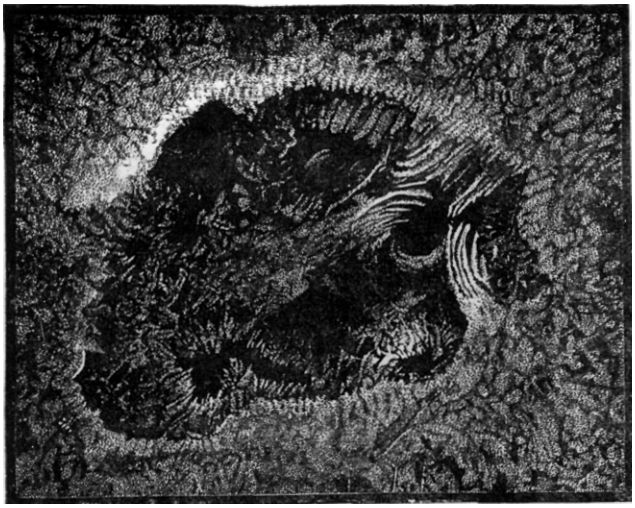

Fig. 14.

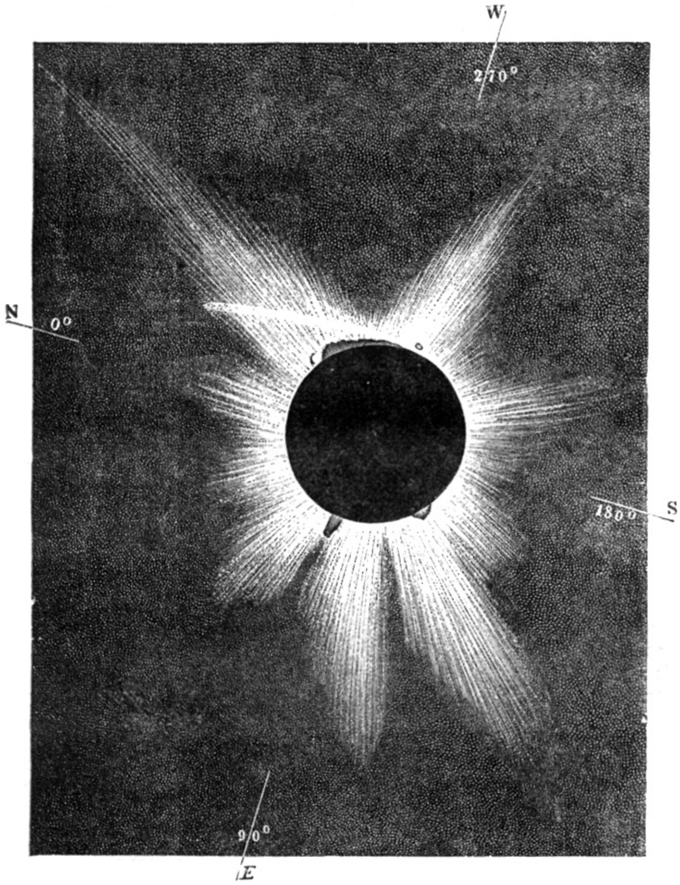

Fig. 15.

In fine, these phenomena attest the existence or an extensive and extremely active solar atmosphere, which grows quickly colder as we ascend from the sun's surface, and a spot with its accompanying faculæ may perhaps be looked upon in the light of a celestial hurricane or hailstorm.

We have in the spot the downrush of a vast quantity of comparatively cold matter from above, and in the faculæ the necessary re-action of this, or the uprush of comparatively hot matter from below, the scale of the operation being occasionally of such a vast magnitude that thirty or forty of our earths might be buried in the pit which represents a spot.

What we have on a large scale in spots and faculæ we have on a small scale all over the sun's disc. When viewed with a powerful telescope the brightness of his disc is found to be far from uniform, the whole surface being made up of bright and dark patches existing side by side. This mottled appearance was first noticed by the elder Herschel, who considered the pores, as he termed them, to be small spots—a conclusion which has since been abundantly verified by the spectroscope. Quite recently M. Janssen, the well-known French observer, has obtained admirable photographs of the sun, exhibiting this mottled appearance on a very large scale. In Fig. 12 we have a picture of a cyclonic sun spot, while in Fig. 13 we have one of faculæ surrounding a spot seen near the sun's edge. Fig. 14 again is a picture by Secchi exhibiting the general mottled appearance round a spot, and the lengthening out of the irregular masses into "straws" in the penumbra.

The phenomena which I have just described are those which are seen projected upon the solar disc. I now go on to describe those which take place near his border. On the occasion of total solar eclipses *red flames*, or *prominences*, are seen to surround the darkened disc of our luminary. At first it was not known whether these belonged to the sun or not, but we are now quite certain that they are true solar appendages. On the same occasions we have, in addition to the red flames, a solar *corona*, or glory, extending sometimes to a very great distance around the solar disc, perhaps even a million of miles or more. Recent observation has proved that this corona is likewise, in part, at least, an undoubted solar appendage.

Having now described the results given us by telescopic observation, let me proceed to those which the spectroscope reveals. Allusion has already been made to the dark lines which occur in the solar spectrum, and which form the characteristic difference betwixt his spectrum and that of the electric light. We have also mentioned the fact that the double solar line D corresponds quite exactly in spectral position with the bright lines given out by incandescent sodium, and that Prof. Stokes conjectured from this coincidence that sodium must exist in the solar atmosphere at a comparatively low temperature.

Professors Bunsen and Kirchhoff in their spectroscopic researches greatly extended this branch of inquiry, showing that many of the dark lines of the solar spectrum are coincident in spectral position with bright lines seen in terrestrial spectra, and concluding that the gaseous substances which afford these spectra must occur in a comparatively cold state in the atmosphere of the sun. The following substances have thus been found to occur in the atmosphere of our luminary—hydrogen, magnesium, calcium, sodium, iron, nickel, manganese, chromium, cobalt, barium, copper, zinc, titanium, aluminium.

The spectroscope has been applied with equal success to the border or limb of our luminary. It was a subject of some surprise that the red flames seen at the time of a total eclipse should be invisible on other occasions; and this perhaps induced observers to imagine that they were not true solar appendages. Independently and nearly simultaneously Janssen and Lockyer showed that these red flames may be rendered visible on ordinary occasions by means of the spectroscope, and they are now the daily study of solar observers. It has been shown that they consist chiefly of incandescent hydrogen, and the reason is very obvious why we cannot see them without the spectroscope. The glare of light around the sun's disc (a strictly terrestrial phenomenon due to reflexion) is in general so strong compared to the light from the red flames, that it is impossible for the eye to distinguish the latter. Now during a total eclipse this glare is removed, and hence the eye can see the red flames. But in the spectroscope we have a means not so much of removing as of diluting the glare, while at the same time the light from the red flames is not diluted. This arises from the fact that the glare is ordinary sun-light, consisting of rays of a great many refrangibilities which are spread out into a long ribbon by the spectroscope, and consequently diluted. On the other hand, that from the red flames consists only of one or two widely-separated refrangibilities which are not spread out, and therefore not diluted. The consequence is that the red flames give us a few bright spectral lines standing out in a solar spectrum so diluted as to be almost invisible. In Fig. 15 we have a representation of the eclipsed sun showing the red flames near the sun, and the corona extending to a great distance around his disc; while in Fig. 16 we have an enlarged view of one of the red flames, showing the curious shapes which these phenomena frequently assume.

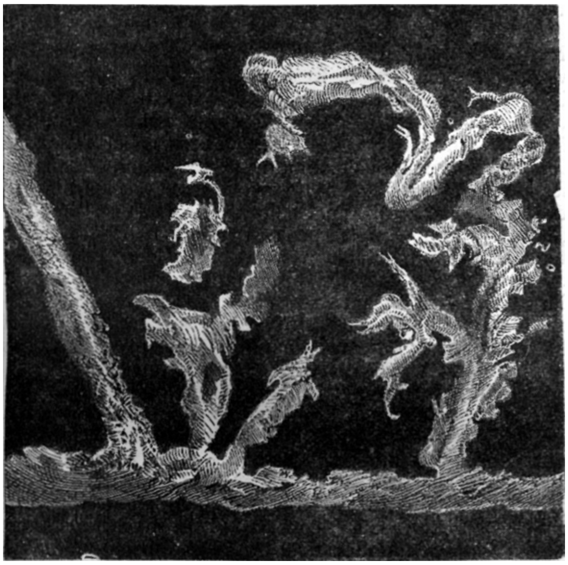

FIG. 16.

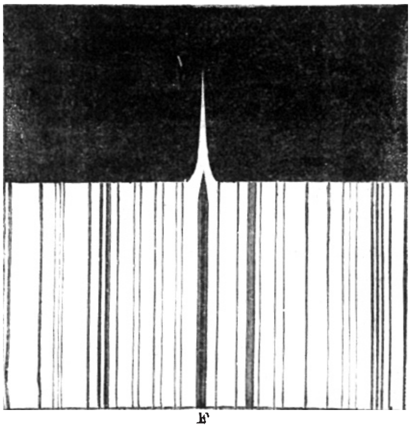

FIG 17

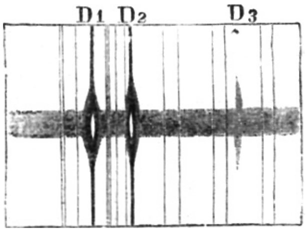

FIG. 18.

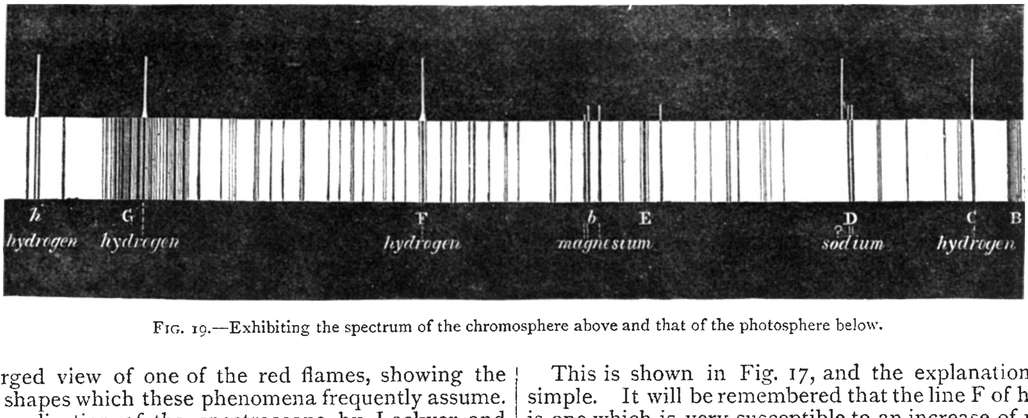

FIG. 19.—Exhibiting the spectrum of the chromosphere above and that of the photosphere below.

The application of the spectroscope by Lockyer and others to selected portions of the solar disc and its surroundings has been most fruitful in its consequences.

One of the first results obtained by Lockyer was the arrow-shaped appearance of the bright line F of the sun's atmosphere, when the slit of the spectroscope is made to form a continuation outwards of the solar radius; that is to say, is perpendicular to the rim of the sun.

This is shown in Fig. 17, and the explanation is very simple. It will be remembered that the line F of hydrogen is one which is very susceptible to an increase of pressure. It is therefore much wider at the bottom of the solar atmosphere than at the top, thus presenting the appearance seen in the figure. When the same observer applied the spectroscope to a sun-spot there was found to be a thickening of various absorption lines in the region of the spot, thus indicating an increase of pressure, and proving that a spot is a phenomenon that occurs below the general surface of the photosphere. In Fig. 18 we have the spectrum of a sun-spot as given by Young, exhibiting this thickening in the double line D, a line which, like F, is eminently susceptible to variations of pressure.

It is, however, erroneous to suppose that the solar atmosphere consists entirely of the red prominences already mentioned. These denote merely (as their name indeed implies) the most violently agitated portions of an atmosphere surrounding the whole sun. Lockyer has named this atmosphere the *chromosphere*, and it extends to an average height of about 4000 miles above the surface of the sun. In Fig. 19 we have a picture of the spectrum of the sun's photosphere below and of the chromosphere above.

One prominent constituent of the chromosphere is hydrogen, but we have here a very strange circumstance. Besides certain well-known hydrogen lines, we have in the chromosphere spectrum an orange-yellow line near D, which we cannot identify with the spectrum of any terrestrial substance. It is probably due to some unknown gaseous body which is mixed up with the hydrogen in the atmosphere of our luminary. Again, in the solar corona, we have a green line which we likewise cannot identify; but our opportunities of examining this region are so few and so transient that any conclusion we may come to with respect to its lines must be regarded as provisional.

BALFOUR STEWART

(*To be continued.*)

BULLETIN OF THE UNITED STATES FISH COMMISSION FOR 1884[1]

TO those who are not already familiar with this publication, it is necessary to explain that the bulletin is a journal whose successive numbers appear at short but irregular intervals, each number containing a small collection of brief articles, notes, and reports, on subjects connected with the work of the Commission. At the end of each year the numbers that have been issued during its course are collected into a single volume and republished.

Some of the notes and articles in the volume for 1884 have but a very remote connection with fish or fisheries, broad as is the interpretation given to those terms by the American Commission. In most cases it may be conceded that the information given has some relation to the supply of human food derived from aquatic organisms, or at any rate some bearing on aquatic life. But it is difficult to see the connection between a report on the sanitary condition of the inhabitants of Old Providence Island and the subject of aquiculture. The Report referred to contains many interesting facts concerning the fecundity, education, and diseases of the people mentioned; it would form a valuable contribution to a medical journal, but the fact that its author was surgeon on board the *Albatross* when he acquired the knowledge of his subject is scarcely sufficient to prevent surprise at the appearance of a sanitary report in the Fish Commission Bulletin.

A considerable proportion of the volume is occupied with reprints and translations from journals and publications of other countries, and nearly all of these are interesting and useful. By the republication of these foreign papers the Bulletin becomes a guide to the knowledge of what is being done in aquicultural enterprise in all parts of the world. Among the reprints are several from British journals—for example, the articles which appeared last year in NATURE on the capture of fish larvæ by Utricularia, and an article on the sea-serpent by Richard A. Proctor, which is taken from the *Newcastle Weekly Chronicle*.

Dr. P. Brecchi's Report on the condition of oyster-culture in France in 1881, originally published in the *Journal Officiel*, is given in full; and there are also several other useful articles on the subject of oyster-culture. Mr. John A. Ryder contributes a description with illustrations of a new sand-diaphragm to be used in the cultivation of oysters in marine ponds, and a report on the condition of the oyster fishery at St. Jerome Creek. Lieutenant Francis Winslow reports on some experiments made in 1883 on the rearing of oyster larvæ. The experiments were not completely successful, and the problem of establishing a working system of oyster-culture on the east coast of America still affords scope for the energies of the Fish Commission.

Several articles and reports contain data from which may be ascertained the extent and success of the efforts which are being made to acclimatise various species of fish in waters far distant from their native homes. The introduction of American fish into French streams has been in many cases successfully accomplished by the Société Nationale d'Acclimatisation. Details of the experiments are given in an article compiled from the monthly bulletin of the Society. Pisciculture and the acclimatisation of new species in Germany is treated in several articles by Max. von dem Borne, who is the founder and owner of a large piscicultural establishment at Berneuchen. The bare record of the successful transmission of whitefish eggs to Nelson, New Zealand, and of American black bass to the river Nene in England, is contained in letters which are reprinted.

Reference to any particular article or subject in the volume, in spite of its extremely heterogeneous character, has been made perfectly easy by the number and completeness of the indexes with which it is provided. In the table of contents the names of all the contributors are given in alphabetical order. A topical synopsis follows, in which the various subjects treated in the articles and notes are given under five headings. Finally, at the end of the book, is an accurate and complete general index.

The *Proceedings* of the United States National Museum is published on the same plan as the *Bulletin* of the U.S. Fish Commission. In the "advertisement" to the volume before us (vol. vii. 1884, Washington, 1885) we are told that the series was commenced in 1878 to provide a means for the prompt publication of descriptions of the new and interesting material which was being sent to the Museum by the activity of the collectors employed in its interest. The articles are published in signatures, one of which is issued whenever printed material to the extent of sixteen pages has accumulated. The produce of each year is issued as an annual volume. The articles consist of papers by members of the scientific corps of the Museum, of papers by others founded on the collections in the Museum, and of interesting extracts from the correspondence of the Smithsonian Institution. The more extensive and complete publications of the Museum are issued in the series of *Bulletins*. Both series are published at the expense of the Interior Department, under the direction of the Smithsonian Institution, and with the supervision of Mr. Spencer F. Baird, director of the National Museum. The present volume, containing a large proportion of articles on fishes, has been edited by Dr. Tarleton H. Bean, curator of the Department of Fishes.

A considerable number of new species of fish are described in this volume. Dr. Bean describes a new species of Coregonus from Alaska, two new species obtained by the Fish Commission, and two from Jamaica. Mr. David Jordan contributes notes on a collection of fishes from Pensacola, Florida, with two new species, one of Exocœtus; and nine other short papers on collections of fishes from Mexico, Florida, and the Mississippi. The same naturalist, in collaboration with Ch. H. Gilbert, gives four, with Seth E. Meek two, and with Joseph Swain six, notes on fishes. The volume contains several additions to the natural history of the Commander Islands in the Behring Sea. One of these is a refutation, by Leonhard Stejneger,

---

[1] *Proc.* of the U.S. National Museum, vol. vii. 1884. (Washington, 1885.)